US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

Enhancing the Power of Game-based Training with Adaptive Tutors

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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@ SFC Paul Ray Smith Simulation & Training Technology Center

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LITE Lab

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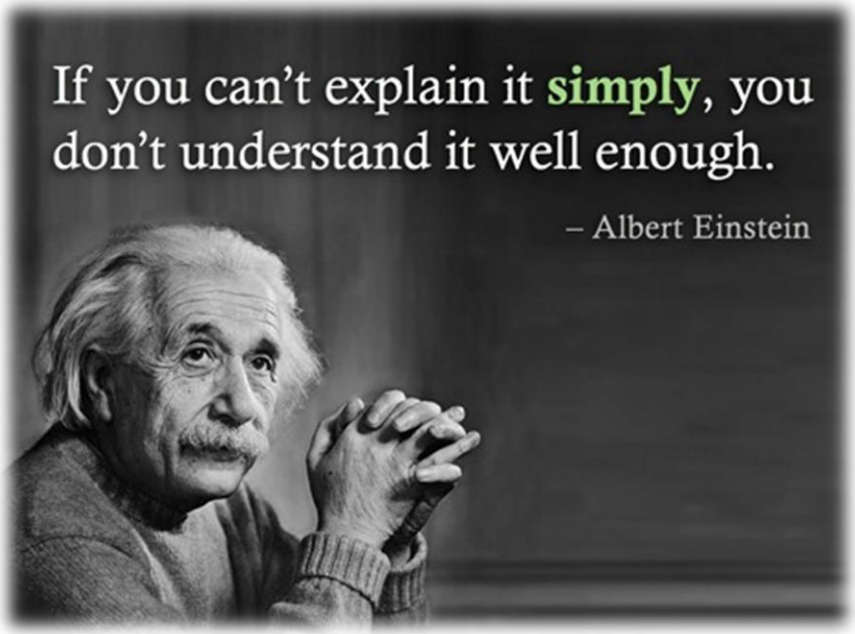
Tutorial Outline

- **Introduction & motivation**
- **Fundamentals of adaptive computer-based tutoring**
- **Adaptive tutoring concepts**
- **Generalized Intelligent Framework for Tutoring (GIFT)**



- **Game-based tutoring demonstration using GIFT**
- **Game-based tutoring design recommendations**
- **Game-based tutoring demonstration using GIFT – time permitting**

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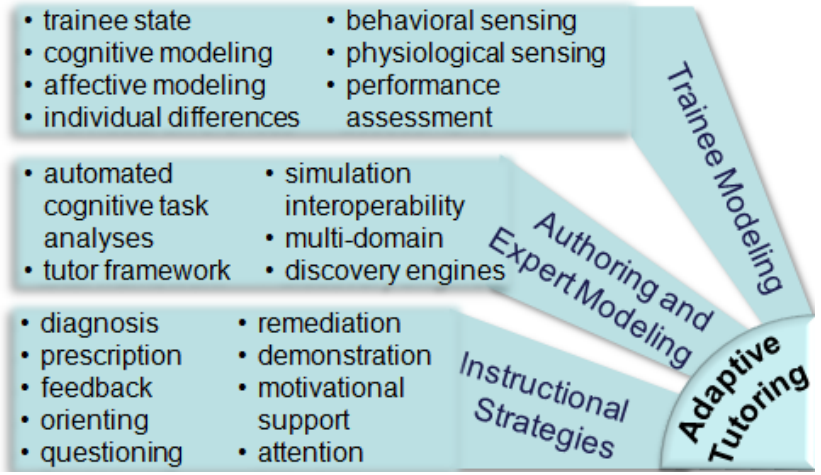
ARL Research Goals

- ***Adaptive Tutoring – personalized, easy to develop, access and use tutoring solutions***



- ***Adaptive Tutoring Research:***

– *Enable computer-based tutors to adapt instruction in real-time to optimize trainee learning (e.g., knowledge acquisition, skill acquisition, retention) by assessing trainee state (e.g. cognition and affect) and influencing their engagement and motivation)*

– *Research and prototype a computer-based tutoring testbed to evaluate adaptive tutoring concepts, models, authoring capabilities, and instructional strategies across various populations, training tasks and conditions, thus enabling summative and formative evaluations including between system evaluations*

Games and Tutors

- Games are engaging
- Games are production units
- Games can support a variety of missions
- Games offer prescriptive feedback based on task performance
- Games are optimized for facilitated learning
- Focus has been on training small unit kinetic tasks

- Computer-based tutors need engaging content
- Tutors are handcrafted
- Tutors are generally domain specific
- Tutors can offer adaptive feedback based on real-time and historical trainee data
- Tutors are optimized for self-regulated learning
- Focus has been on training individual non-kinetic tasks

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Motivation for an Adaptive Tutor

- **A Warfighter's Tutor MUST:**
  - have comprehensive knowledge of the operational context during training
  - have the capability to adapt to the learner's fatigue and cognitive load
  - prepare the Warfighter to become his/her individual best
  - motivate the Warfighter to become a beneficial contributor to the learning of fellow Warfighters (social learning)
  - allow Warfighters to "train as they fight"

MG Nick Justice, Commanding General, US Army RDECOM
Senior Leader Panel on Adaptive Training, IITSEC, Orlando, December 2011

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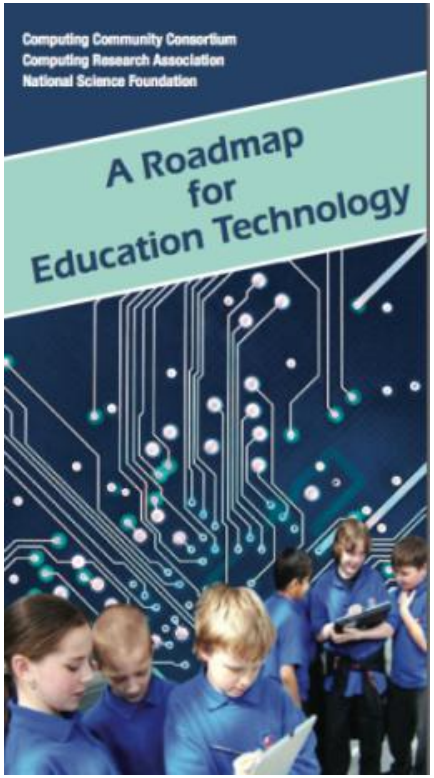
Grand Challenges for Educational Technology

- **Personalize Education**
- **Assess Student Learning**
- **Support Social Learning**
- **Diminish Boundaries**
- **Develop Alternative Teaching Methods**
- **Enhance the Role of Stakeholders**
- **Address Policy Changes**



Woolf, B. P. (2010). *A Roadmap for Education Technology. National Science Foundation # 0637190*

Fundamentals of adaptive computer-based tutoring

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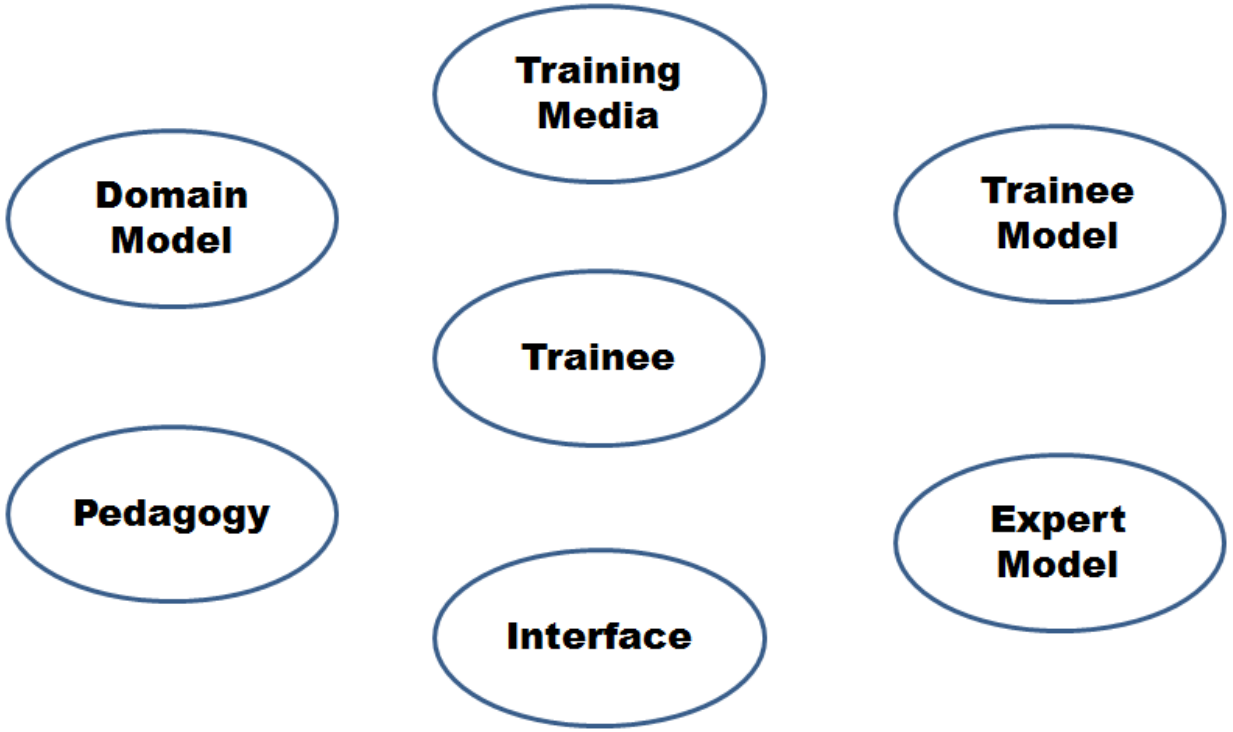
Elements of a computer-based tutor

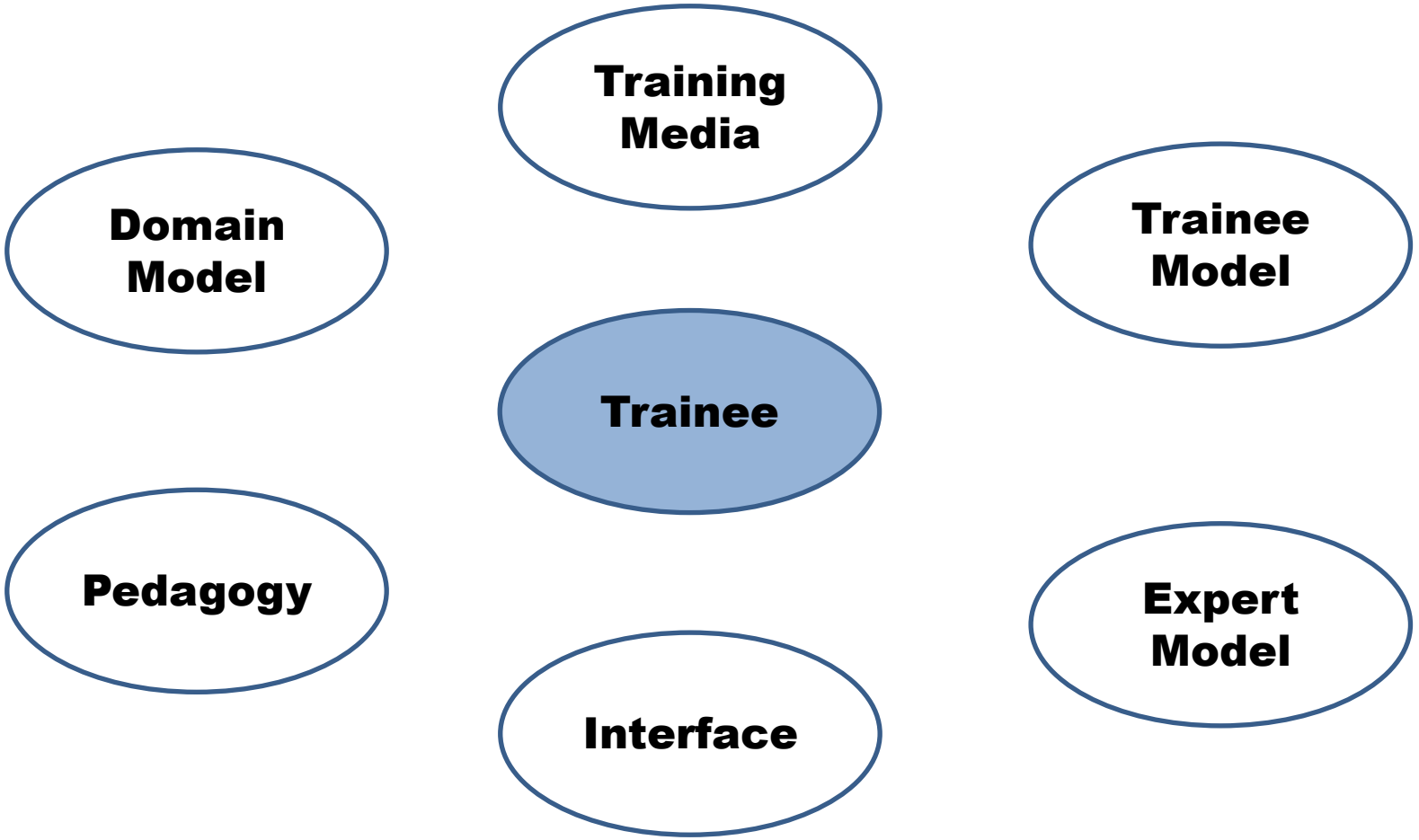


Beck, J., Stern, M., and Haugsjaa, E. (1996) *Applications of AI in Education*, ACM Crossroads.

Sottilare, R. and Gilbert, S. (2011). *Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games*. Authoring Simulation and Game-based Intelligent Tutoring workshop at the Artificial Intelligence in Education Conference (AIED) 2011, Christchurch, New Zealand, June 2011.

Sottilare, R. and Proctor, M. (2012; *in press*). *Passively classifying student mood and performance within intelligent tutoring systems (ITS)*. Educational Technology Journal & Society. Volume 15, Issue 2.

Elements of a computer-based tutor



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Elements of a computer-based tutor

also known as the learner, user, student or tutee

individuals

Trainee

teams

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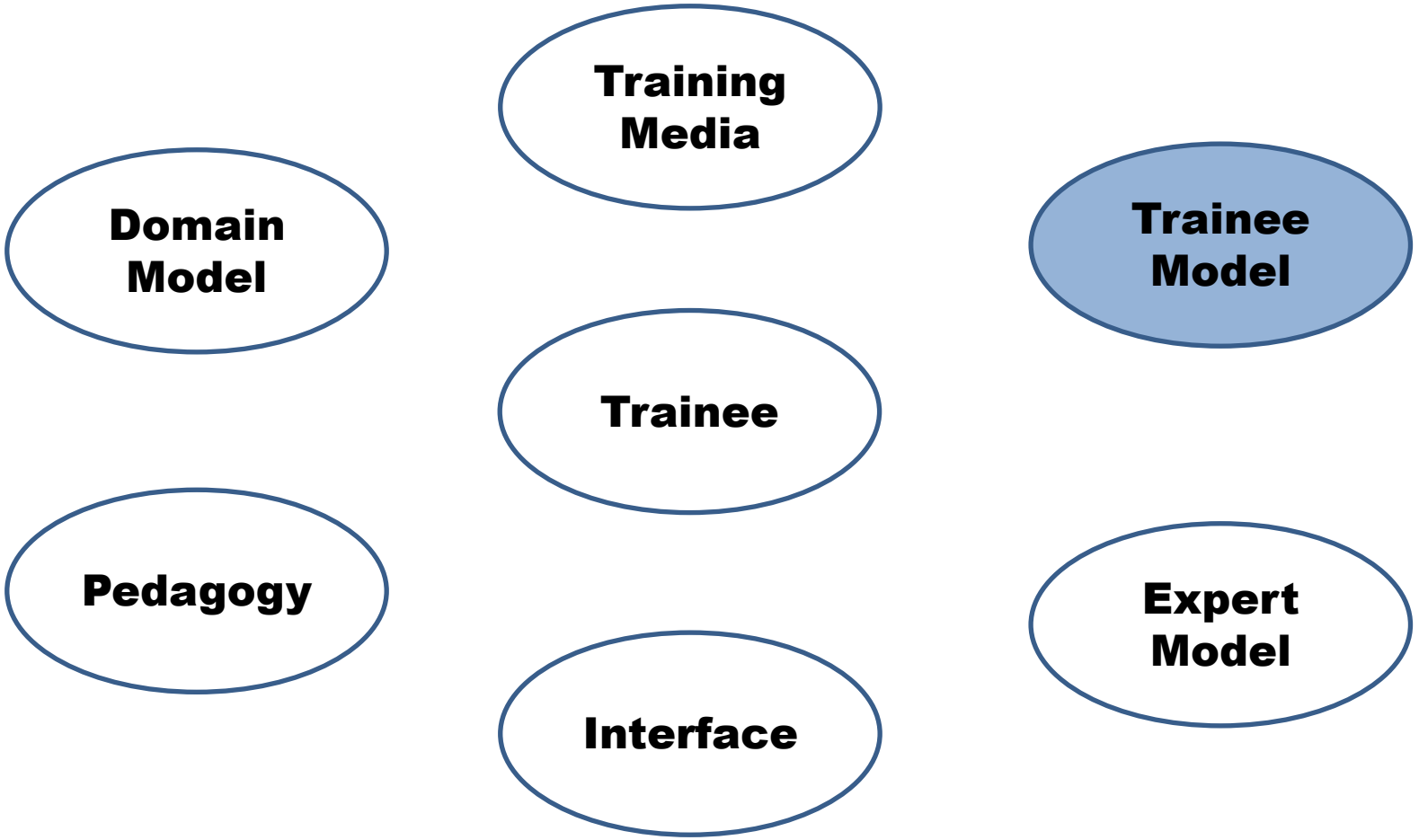
Elements of a computer-based tutor



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Elements of a computer-based tutor

domain-independent

basis for "adaptive tutoring"

what the tutor knows about the trainee...

- ***progress toward objectives***
- ***actions taken through the interface (e.g., fire a weapon)***
- ***sensor data (e.g., behavioral, physiological)***
- ***survey data***
- ***other historical data (e.g., previous performance)***

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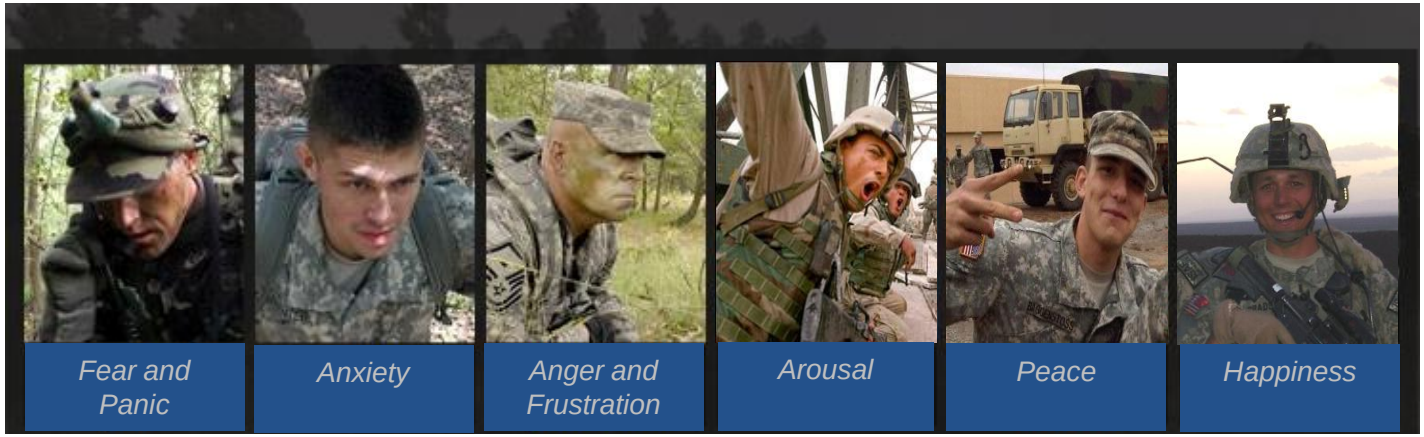
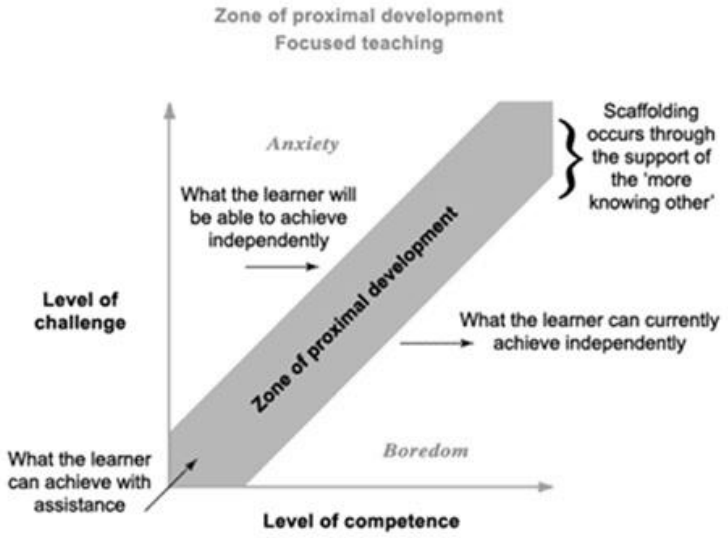
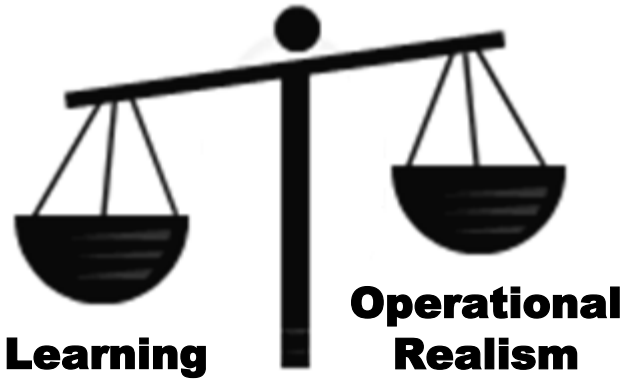
Cognition and Affect



Assessing cognition and affect during training is on the critical path of adapting to the trainee's individual learning needs





Cognition and Affect

- **Cognitive learning**
  - **behaviors indicating increasingly complex and abstract mental capabilities**
  - **Remembering (low)**
  - **Understanding**
  - **Applying**
  - **Analyzing**
  - **Evaluating**
  - **Creating (high)**

Source: Anderson and Krathwohl's Taxonomy (2000) aka Bloom's Revised Taxonomy

- **Affective learning**
  - **behaviors indicating emotional growth**
  - **Receiving (awareness)**
  - **Responding (interest)**
  - **Valuing (appreciation)**
  - **Organizing (responsibility)**
  - **Characterizing (commitment)**

Source: Krathwohl's Taxonomy

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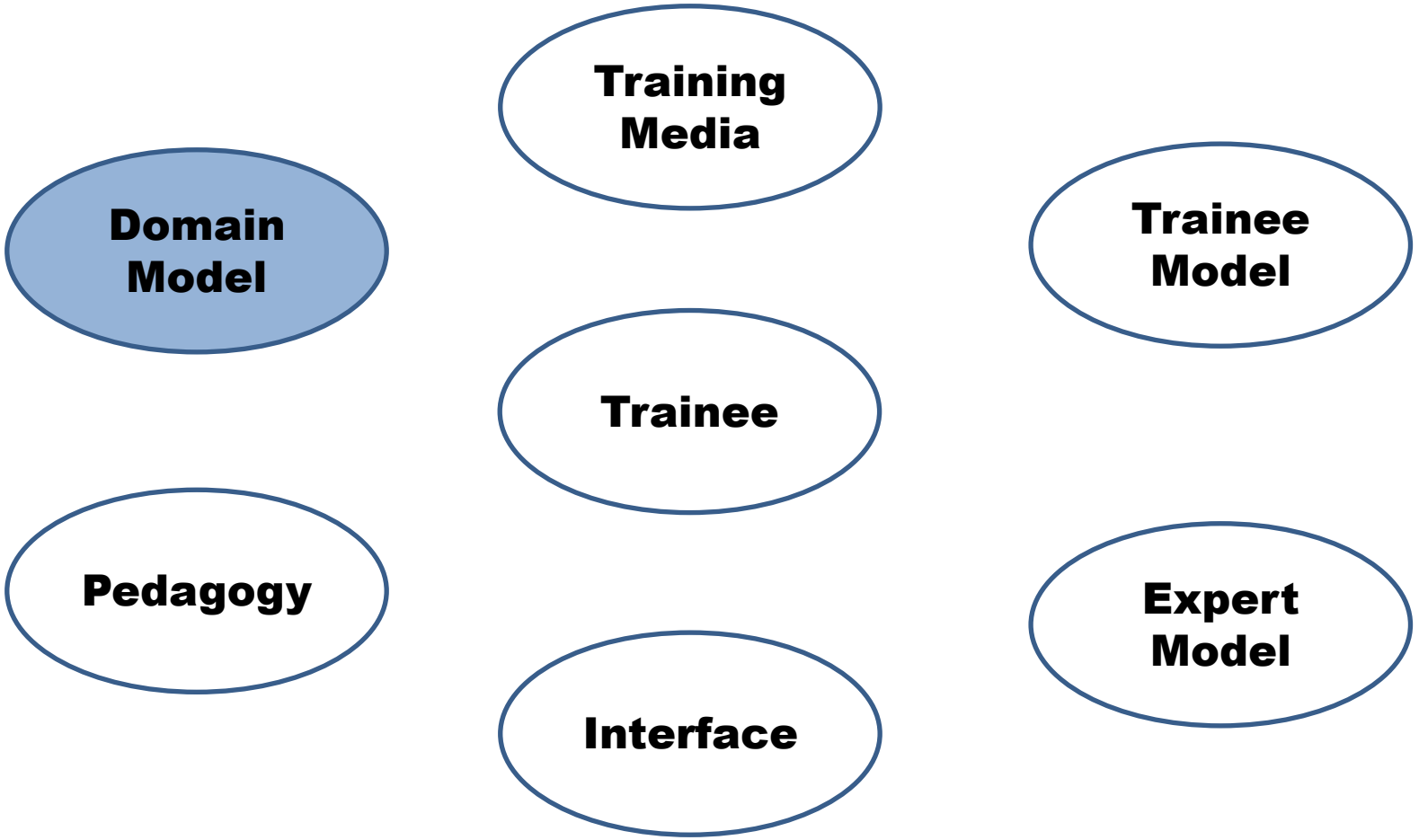
Elements of a computer-based tutor



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Elements of a computer-based tutor

domain-dependent

Domain Model

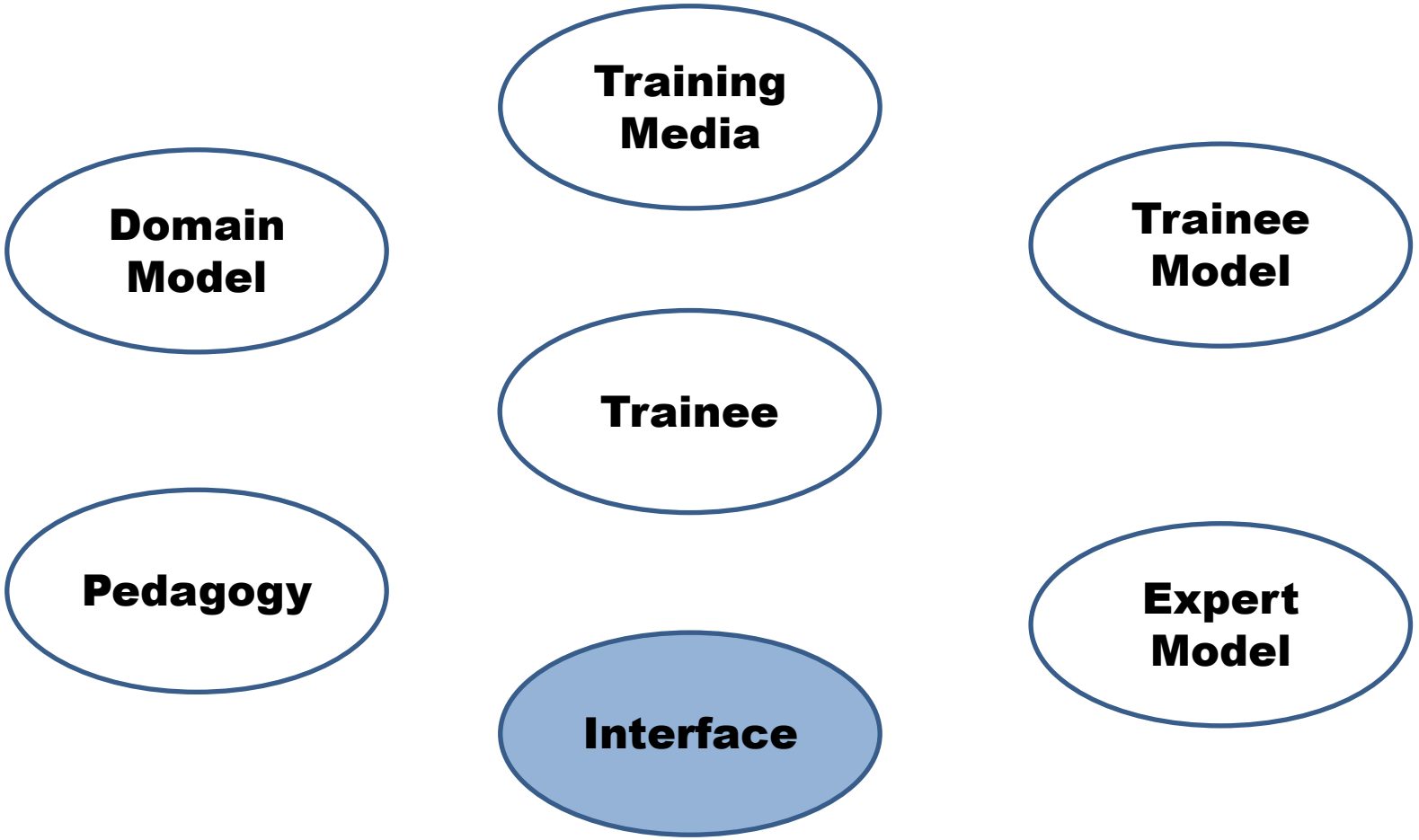
Table 1
Physical and Cognitive Dimensions Used in Rating Tasks, According to Task Domain *

Domain and dimension	Activity
Physical	
Muscular strength	exert force, apply speed and power, lift, pull
Endurance	sustain physical activity resulting in increased heart rate
Coordination	flex, twist or bend limbs of the body, maintain balance, coordinate movements of the arms, legs, or body in skilled action
Cognitive	
Perceptual input	search for and acquire information, observe, read, monitor, scan, identify, locate
Mental operations	compare and contrast information, organize, analyze, categorize, generate hypotheses, apply principles
Output and response	make decisions, solve problems, make judgments, evaluate

- ***the stuff you want the trainee to learn…***
- ***the tasks/problems presented to the trainee…***
- ***the conditions in which the learning takes place***

* Driskell, J.E., Copper, C. and Moran, A. (1994). *Does mental practice enhance performance?* Journal of Applied Psychology, Vol 79(4), Aug 1994, 481-492.

Elements of a computer-based tutor



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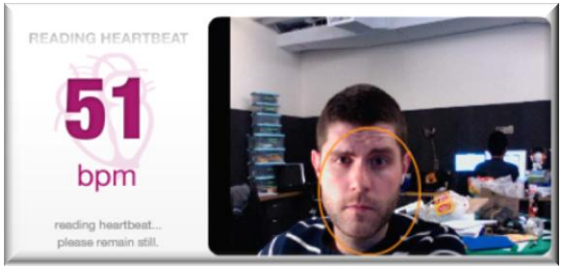

Natural Language Interface

the trainee's access to the training environment...
and the computer's capability to collect data about the trainee

data & language I/O
&
sensory stimuli

Interface

domain-independent

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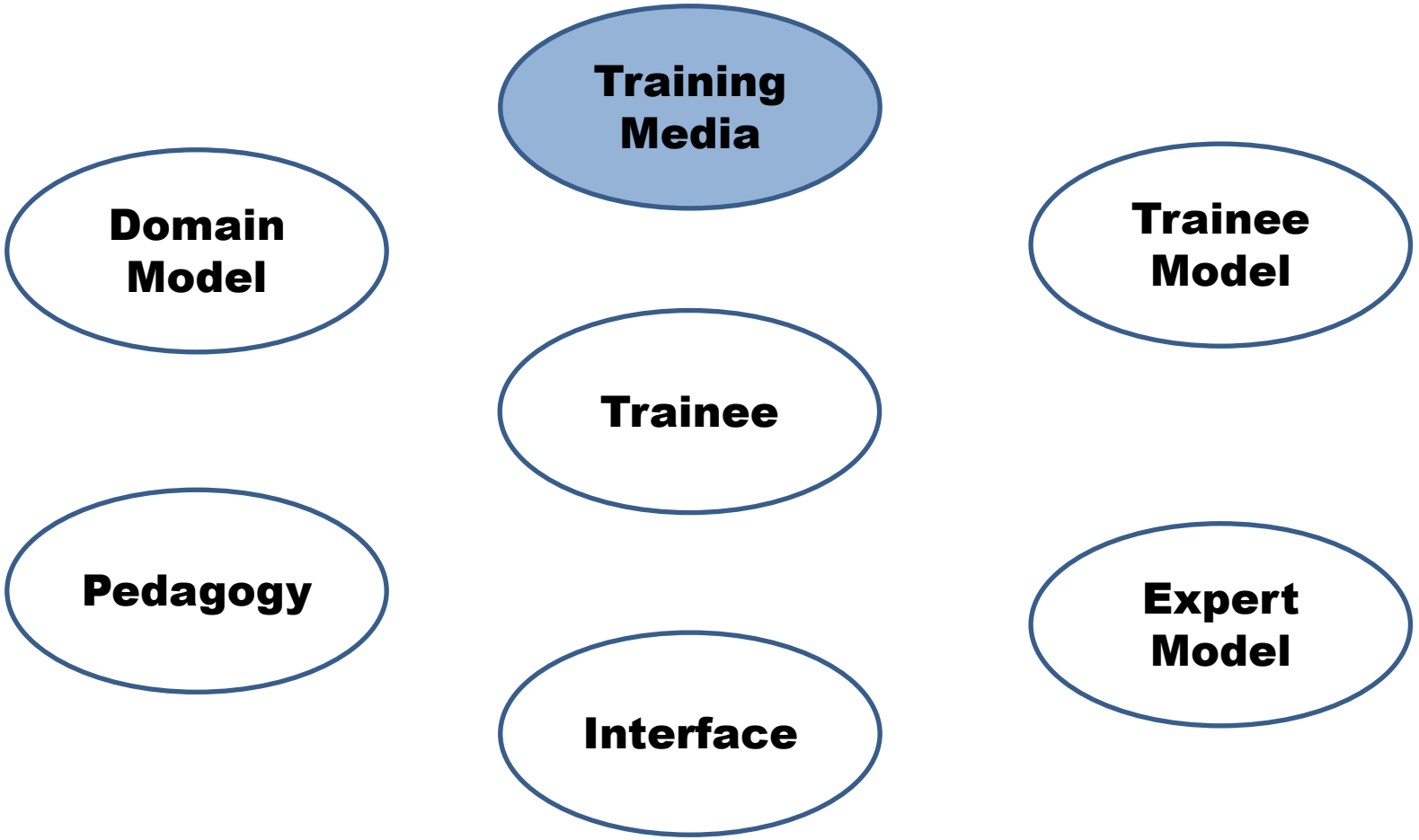
Elements of a computer-based tutor



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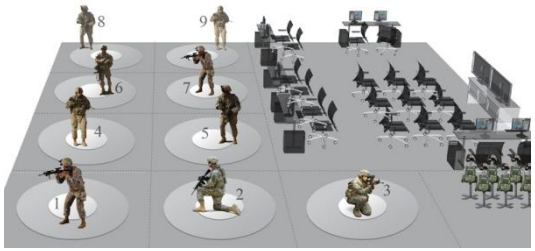
Elements of a computer-based tutor

Training Media

generally domain-dependent, but games offer some domain-independence… many missions can be trained in games

the training environment… computer media used to deliver training…



- ***simulation, game, powerpoint…***
- ***ideally, adapted to support individual/team learning needs***

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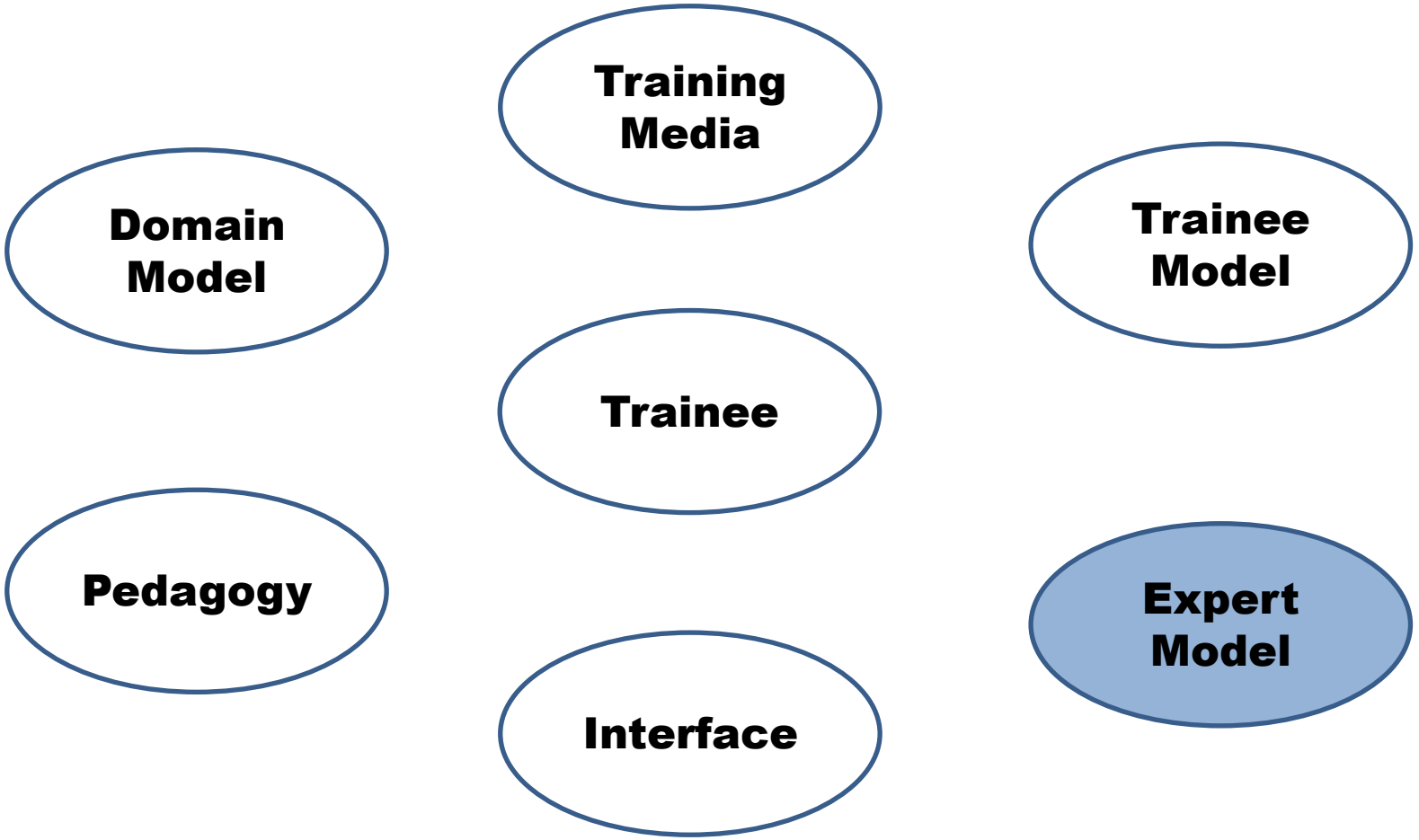
Elements of a computer-based tutor



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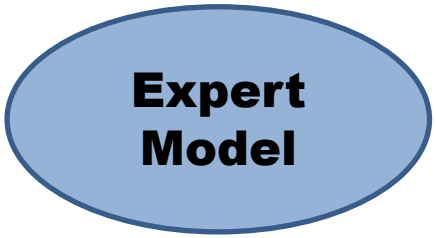
Elements of a computer-based tutor

perceptions, decisions and actions of an expert …

- ***sets standards modeled on an "ideal trainee"***
- ***defines mastery standards***
- ***compares trainee actions to determine progress***

domain-dependent



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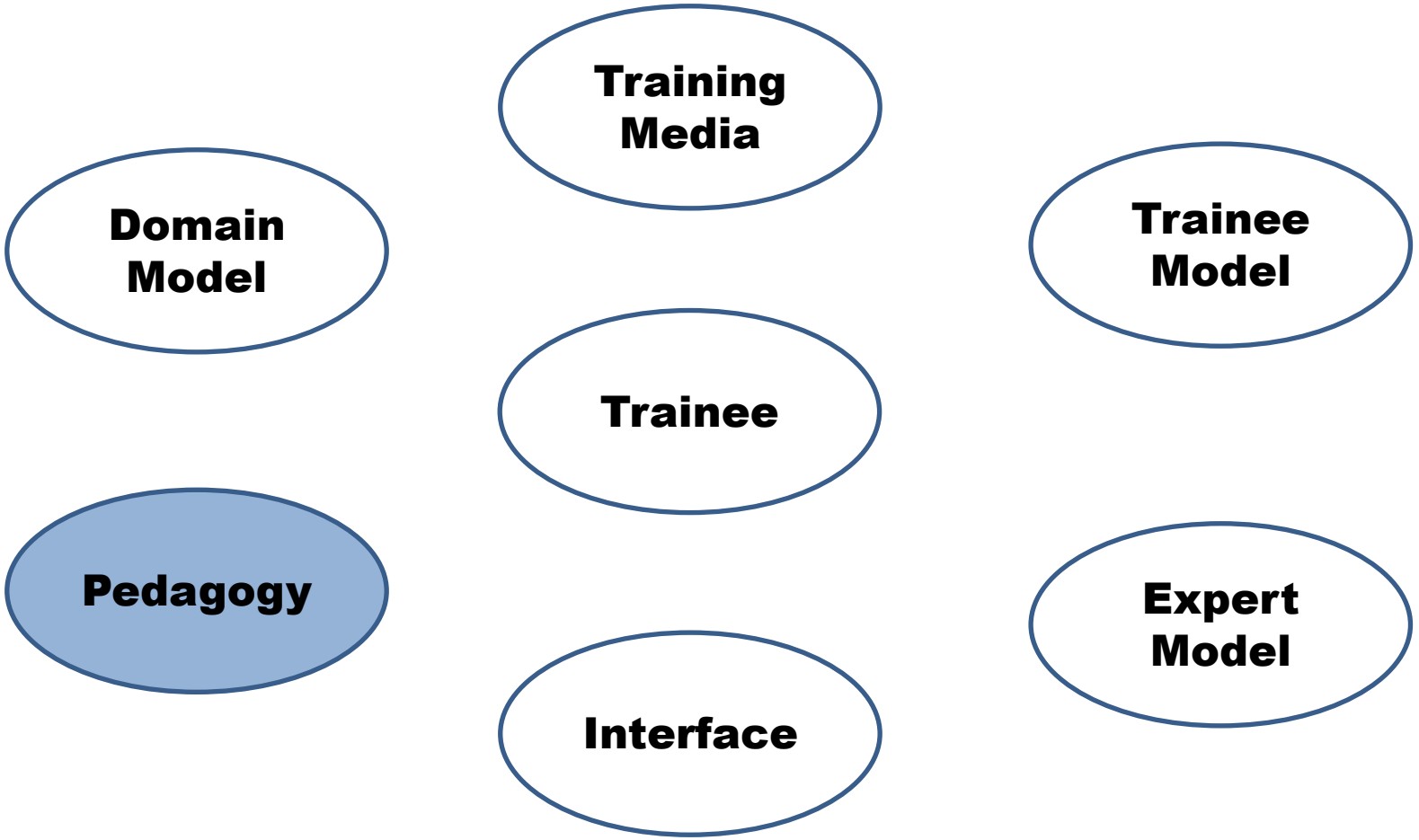
Elements of a computer-based tutor



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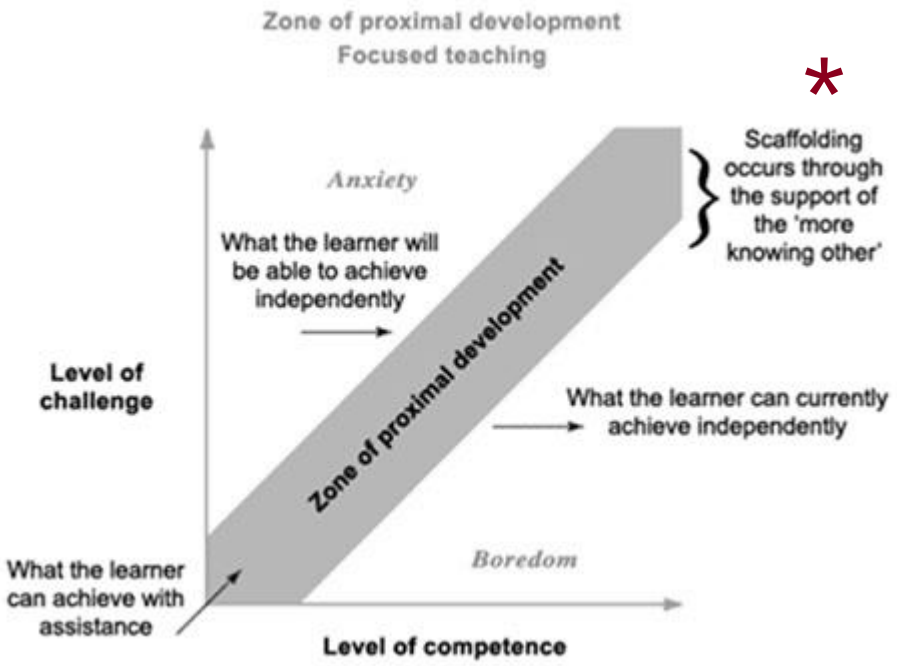
Elements of a computer-based tutor

how you want the trainee to learn…

- ***pace***
- ***challenge level***
- ***support***
- ***selection of instructional content, instructional strategies and feedback***



Pedagogy

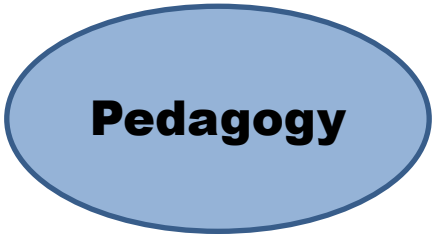
we want pedagogy to:

- ***adapt to trainee's learning needs***
- ***be domain-independent***

* Vygotsky, L.S. (1978). *Mind and society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

INSPIRE Model of Tutoring

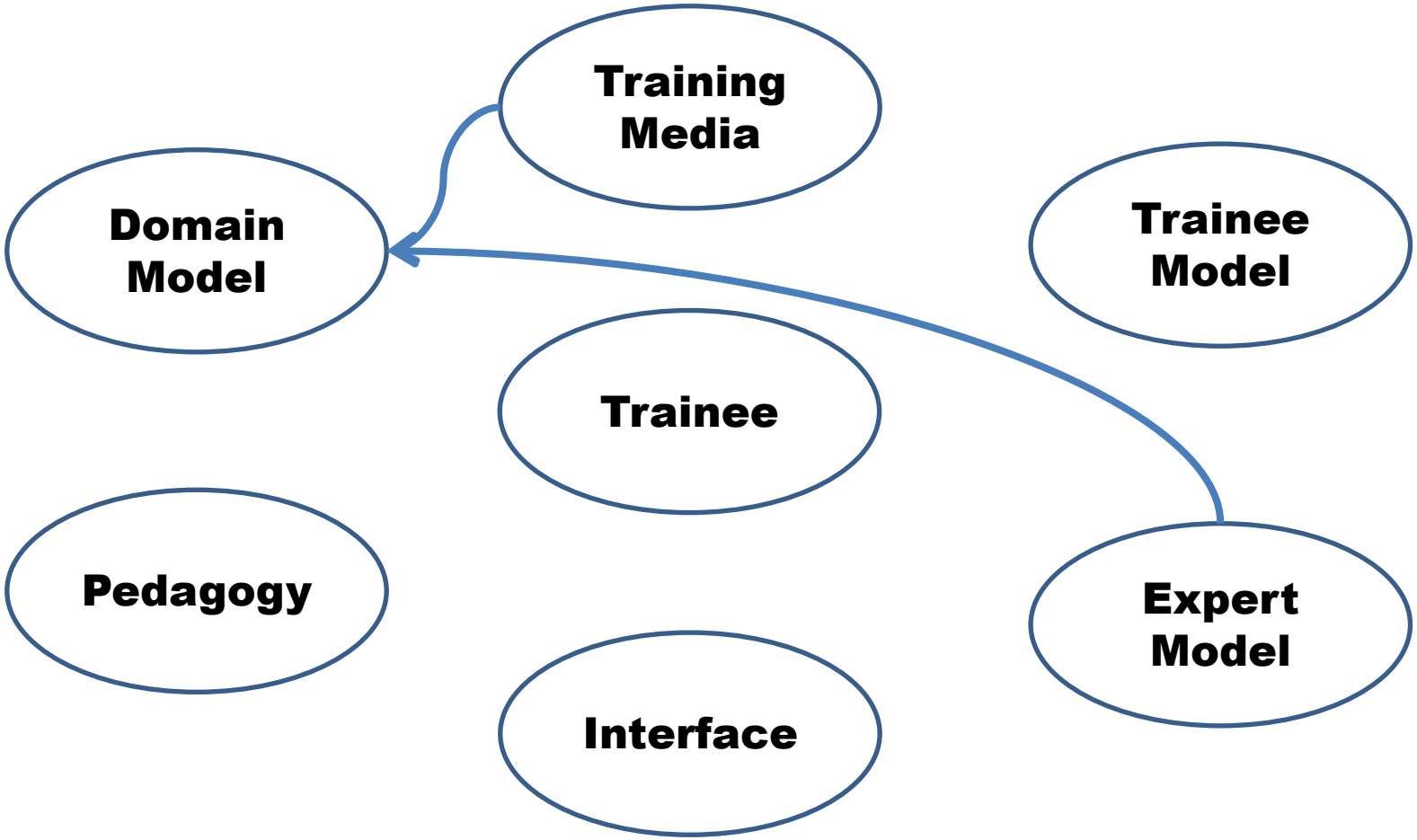
***Intelligent* – credible**
***Nurturing* – supportive**
***Socratic* – questions, not directions; hints not answers**
***Progressive* – planned, structured and systematic**
***Indirect* – less explicit or profuse positive feedback**
***Reflective* – ask students to discuss process, explain answers and generalize problem to other domains**
***Encouraging* – bolster confidence; challenge students**



INSPIRE model of tutoring: based on exhaustive studies of expert human tutors (Lepper, Drake & O'Donnell –Johnson (1997).

Lepper, M. R., Drake, M., & O'Donnell-Johnson, T. M. (1997). Scaffolding techniques of expert human tutors. In K. Hogan & M. Pressley (Eds), Scaffolding student learning: Instructional approaches and issues (pp. 108-144). New York: Brookline Books.

Elements of a computer-based tutor



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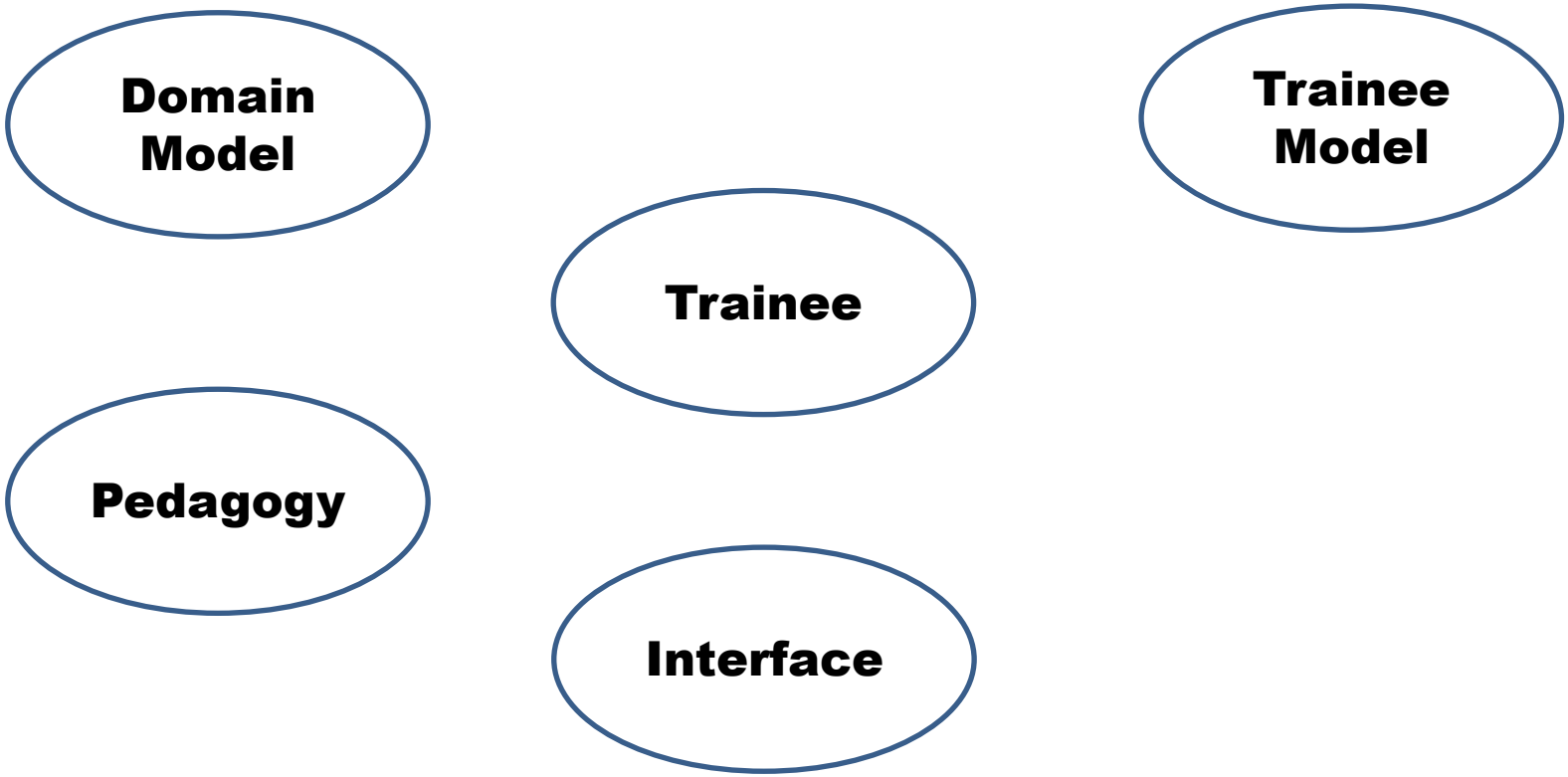
Elements of a computer-based tutor



Adaptive game-based tutoring schema

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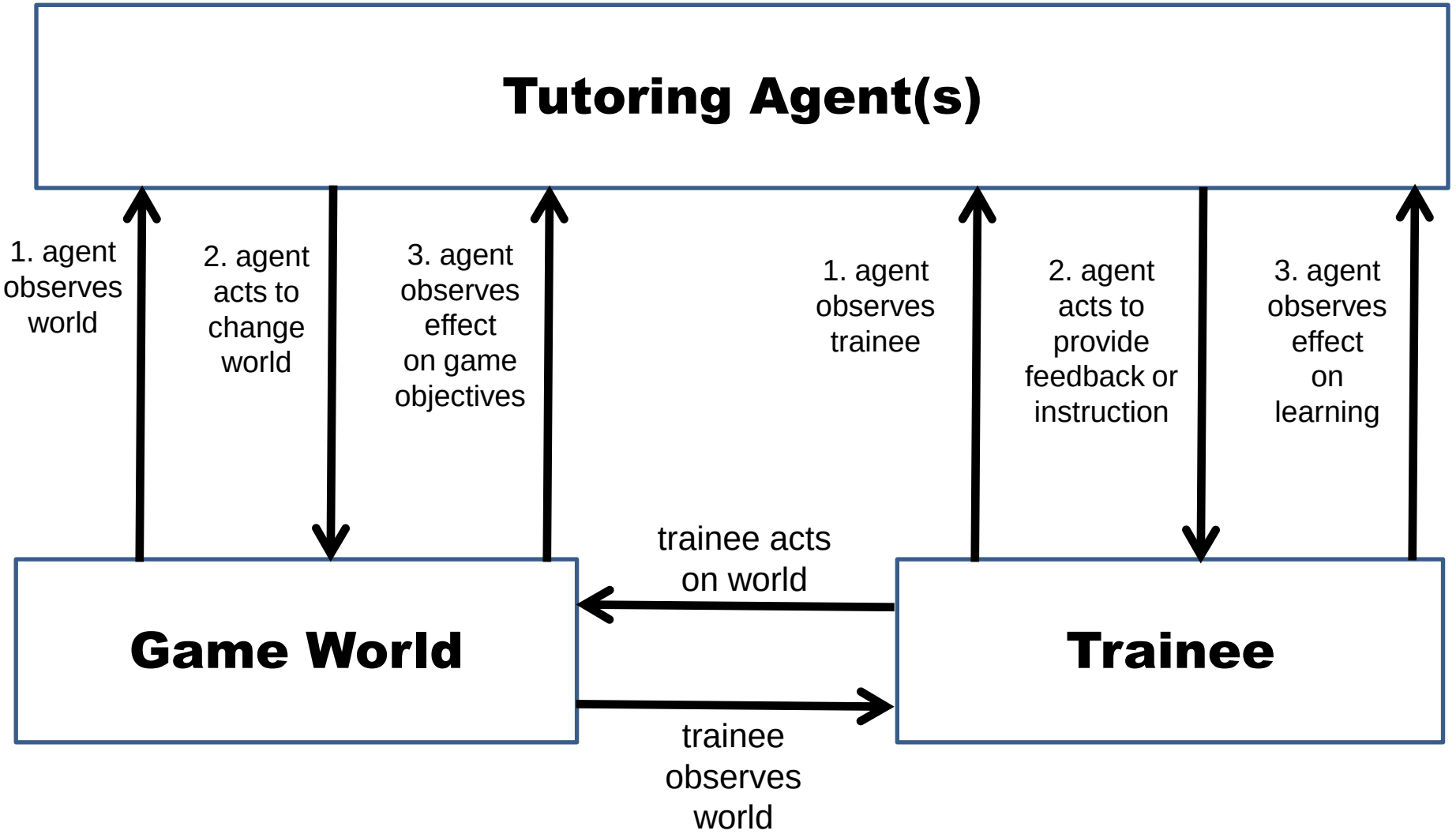
Interaction in game-based tutoring



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Adaptation Schema

- **Macro-adaptation for learning**
  - **pre-training tailoring based on historical data**
  - **initializes trainee model**
  - **affects domain content and objectives**
  - **evaluates recency…**
    - **e.g., prerequisites taken 20 years ago vs. last 6 months**
- **Micro-adaptation for learning**
  - **in-situ tailoring of training based on:**
    - **performance, cognitive & affective states derived from sensor data**
  - **near real-time assessment of sensor data**
  - **maintains trainee model**
  - **evaluates recency…**
    - **e.g., localized vs. global effects in feedback decisions**

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Making Adaptive Tutoring Practical

- **Low-cost, passive sensing of trainee physiology and behaviors**
- **Near real-time classification of trainee cognition and affect**
- **Near real-time selection of optimal instructional strategies (questions, reflection, hints, prompts, pumps…) based on:**
  - **Cognition (attention, engagement, understanding…)**
  - **Affect (personality, mood, emotions, motivation)**
  - **Historical trainee data (performance, preferences…)**
  - **Training context**
- **Automated authoring**
  - **Automate trainee and expert modeling**
  - **Standardized, mostly domain-independent tutor components and processes**
  - **Leverage games for tutoring**
- **Enhanced human-agent interaction**
  - **Content and strategy presentation**
  - **Virtual humans (optimized to support learning)**

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Generalized Intelligent Framework for Tutoring

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Generalized Intelligent Framework for Tutoring

1 GIFT
- 1.1 Modeling
  - 1.1.1 Trainee Modeling
    - 1.1.1.1 Sensing Technologies
      - 1.1.1.1.1 Behavioral Sensing
      - 1.1.1.1.2 Physiological Sensing
    - 1.1.1.2 State Classification
      - 1.1.1.2.1 Affective State Classification
        - 1.1.1.2.1.1 Emotion Classification
        - 1.1.1.2.1.2 Motivation Classification
      - 1.1.1.2.2 Cognitive State Classification
        - 1.1.1.2.2.1 Workload Classification
        - 1.1.1.2.2.2 Engagement Classification
  - 1.1.2 Expert Modeling
  - 1.1.3 Domain Modeling
- 1.2 Instruction
  - 1.2.1 Content
    - 1.2.1.1 Content Authoring
    - 1.2.1.2 Content Delivery
    - 1.2.1.3 Content Validation
  - 1.2.2 Instructional Strategies
    - 1.2.2.1 Instructional Strategy Authoring
    - 1.2.2.2 Instructional Strategy Delivery
    - 1.2.2.3 Instructional Strategy Assessment

GIFT

open source tools, standards and best practices to:

- **author tutoring systems**
  - **domain content**
  - **instructional strategies**
  - **human-system interaction**
  - **expert models**
- **provide instruction**
  - **present content**
  - **implement strategies**
- **assess effectiveness**
  - **learning effect size**
  - **performance effect size**

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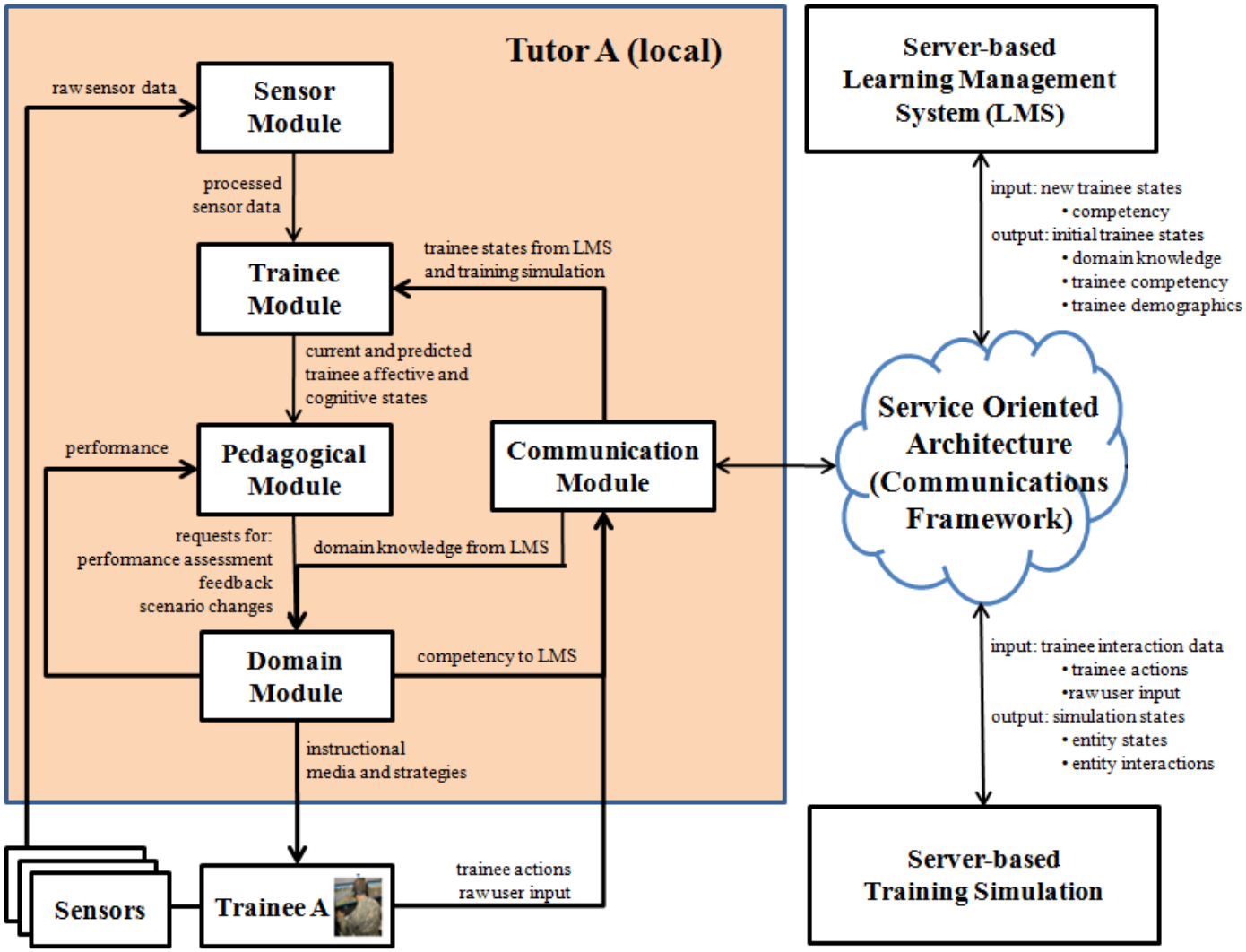
Individual tutoring schema



GIFT

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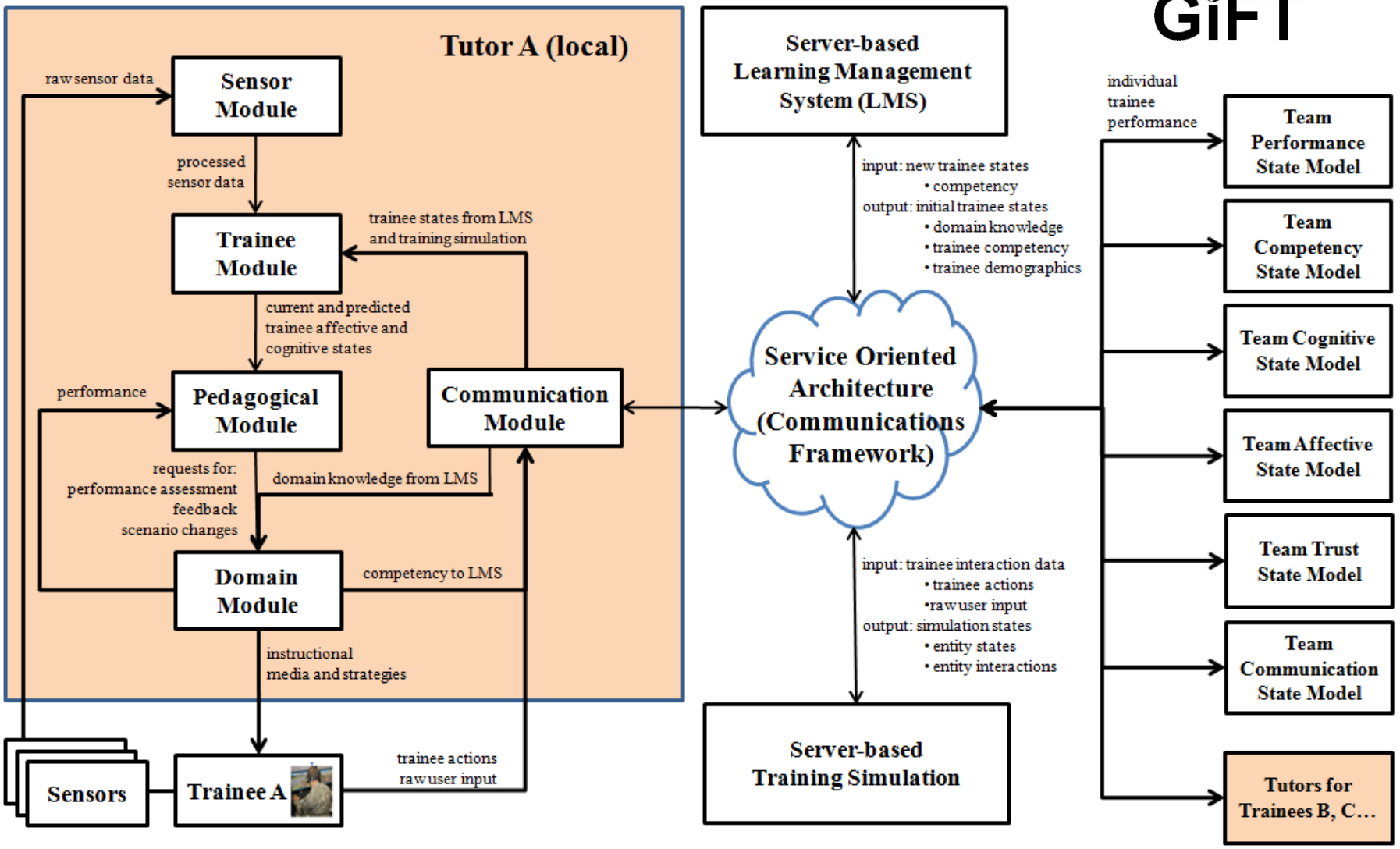
Team tutoring schema



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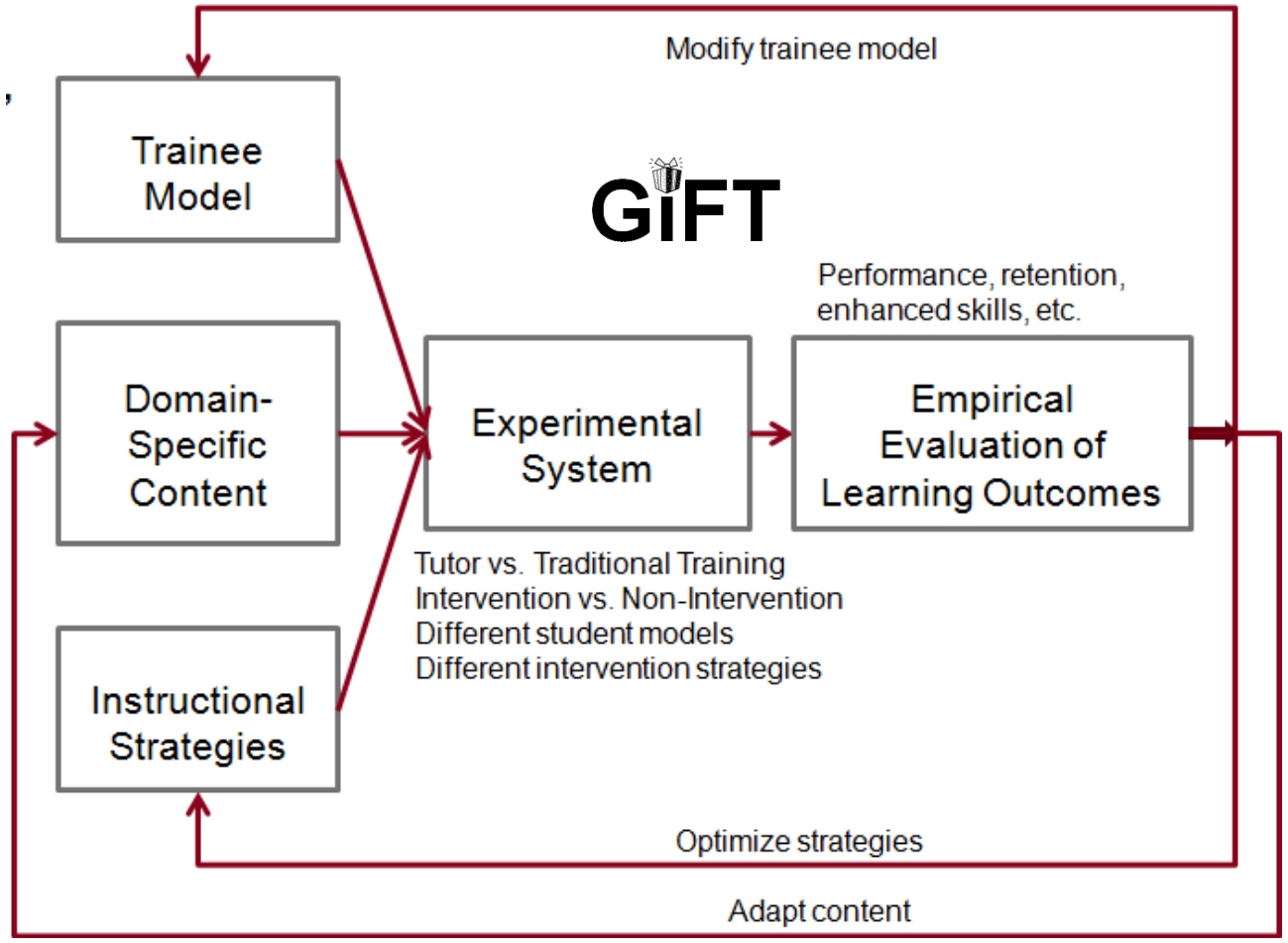
Assessment schema



Generalized Intelligent Framework for Tutoring (GIFT)

- *Open source*
- *Modular , reusable components*
- *Agent-based capabilities*
- *Server-based architecture*
- *Sensor interface library*
- *Scenario library*
- *Survey library tool*
- *Game-based tutoring interface*
- *Tutoring assessment standards*

- *Tools to support:*
  - *Automated Authoring*
  - *Concept Assessment*
  - *Individual training*
  - *Small unit training*
  - *Desktop training*
  - *Kinetic training*
  - *Distributed (mobile) learning*
  - *Social learning*

- *Coming soon…*
  - *AutoTutor interface*
  - *Automated Expert Modeling Methods*
  - *Virtual Human interface*

Assess → Model → Predict → Adapt → Influence Learning

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Game-based tutoring demonstration using GIFT

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Game-based tutoring design recommendations

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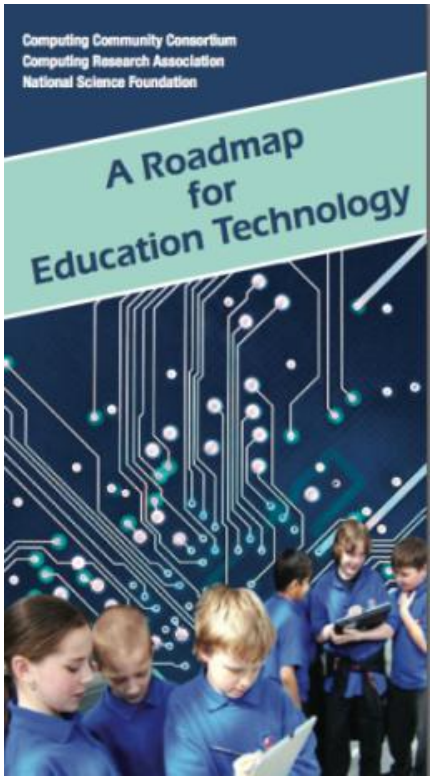
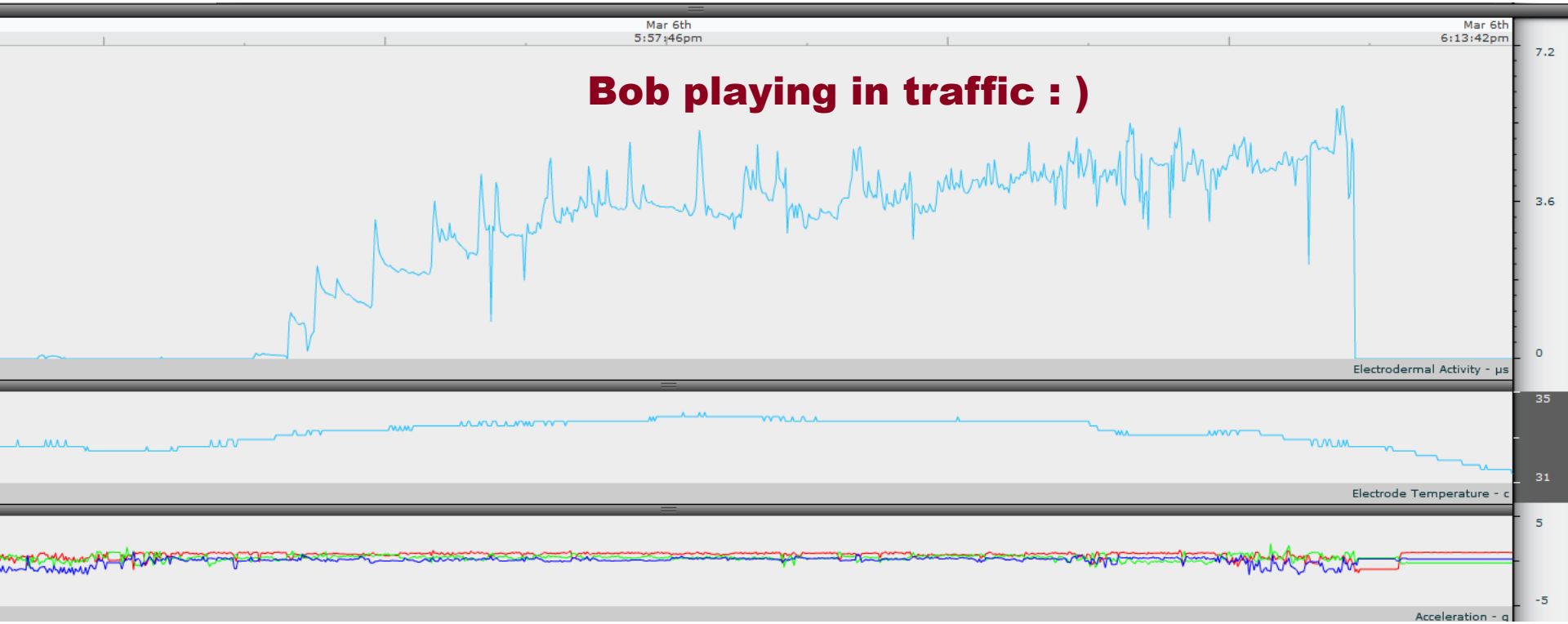
Next Steps for Educational Technology

- **User Modeling**
- **Mobile Learning**
- **Networking Tools**
- **Serious Games**
- **Intelligent Environments**
- **Educational Data Mining… Big Data**
  - **Tailored content development**
  - **Methods to generate expert models**
- **Rich Interfaces**



Adapted from: Woolf, B. P. (2010). *A Roadmap for Education Technology. National Science Foundation # 0637190*

Passive Sensing



Research question: what is the minimum set of sensors needed to assess engagement, workload, motivational level and emotional state?

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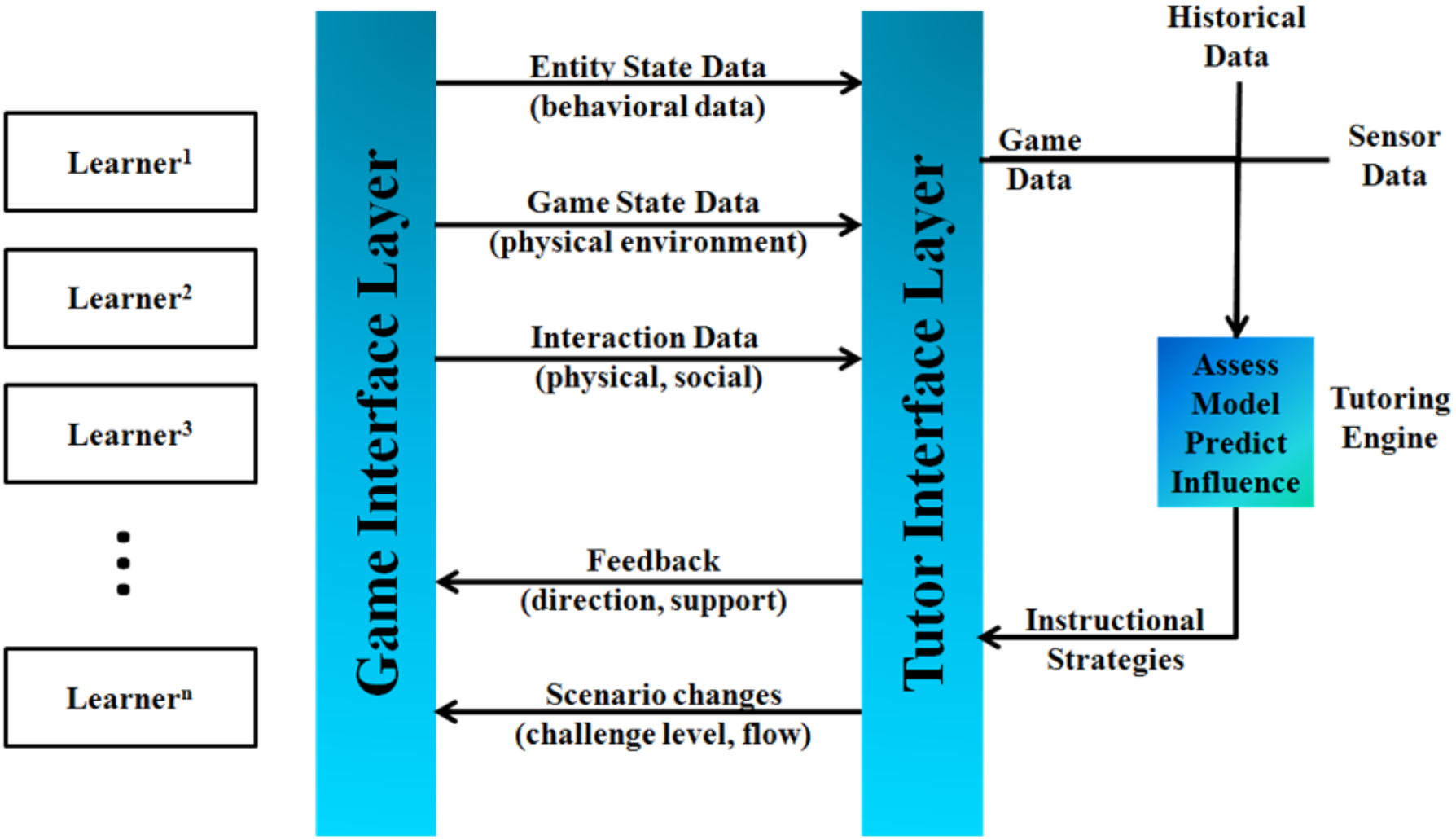
Standards for Game-based Tutor Interaction



Sottilare, R. and Gilbert, S. (2011). Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games. Authoring Simulation and Game-based Intelligent Tutoring workshop at the Artificial Intelligence in Education Conference (AIED) 2011, Christchurch, New Zealand, June 2011.

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Standards to Assess/Compare Tutor Performance

- **Adapt to the learner better than a human tutor**
- **Enable learning better than a human tutor**

- **Fully perceive learner behaviors and physiology through remote sensing**
- **Fully support mobile training**
- **Are consistently accurate (near 100%) in classifying the learner's cognitive state in near real-time**
- **Have an optimized repertoire of instructional strategies**
- **Are automatically integrated with a variety of training platforms (e.g., serious games, commercial/military training simulations)**

Sottilare, R. and Gilbert, S. (2011). Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games. Authoring Simulation and Game-based Intelligent Tutoring workshop at the *Artificial Intelligence in Education Conference (AIED) 2011*, Auckland, New Zealand, June 2011.

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Challenges Ahead for Game-based Tutoring

- **Limitations/challenges imposed by desire to generalize across:**
  - **different game platforms and training domains**
- **Limited push/pull of data through game interface:**
  - **DIS/HLA interfaces… not all games have these interfaces**
  - **Scripting interfaces… need standard interfaces**
  - **Remotely controlling game entities using intelligent agents**
- **Applying context to trainee state assessment**
- **Need for terrain reasoning in the tutor**
  - **understanding the significance of location to learning objectives**

Challenges Ahead for Game-based Tutoring

- **Translation of subject matter expert knowledge into tutor expert model**
  - **automating knowledge acquisition to reduce development costs**
  - **validating expert models**
- **Optimizing instructional strategies for individuals and teams**
- **Recognition of learning need events by the tutor***
  - **when presented with new learning opportunities**
  - **when motivated to learn more**
  - **when trying to recall information**
  - **when things change**
  - **when something goes wrong**

*** Adapted from: Five Moments of Learning Need, Conrad Gottfredson, co-author of "Innovative Performance Support"**

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Invitation to submit

Adaptive and predictive computer-based tutoring track

DHSS 2012

International Defense and Homeland Security Simulation Workshop

September 19-21, 2012

Vienna, Austria

http://www.msc-les.org/conf/dhss2012/index_file/APCBT.htm

Key Dates:

Submissions of Extended Abstracts (2 pages):	**April 12, 2012**
Notification of acceptance:	**May 12, 2012**
Final Camera-Ready Submission:	**June 12, 2012**
Early Registration:	**July 01, 2012**

Homework

Selected Readings:

Woolf, B. P. (2010). *A Roadmap for Education Technology*. National Science Foundation # 0637190

Sottilare, R. and Gilbert, S. (2011). *Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games*. Authoring Simulation and Game-based Intelligent Tutoring workshop at the Artificial Intelligence in Education Conference (AIED) 2011, Christchurch, New Zealand, June 2011.

Committee on Science Learning: Computer Games, Simulations, and Education; National Research Council. (2011). In M.A. Honey and M. Hilton (Eds.) *Learning Science Through Computer Games and Simulations*.. National Academies Press.

Coming soon:

- Generalized Intelligent Framework for Tutors (GIFT) Build 1.0
- GIFT Interface Control Documentation
- GIFT Research and Design Documentation

Unclassified – Distribution A – Unlimited

Thank you for your attention!

Questions?

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Unclassified – Distribution A – Unlimited

Game-based tutoring demonstration using GIFT

Unclassified – Distribution A – Unlimited